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Special Article

A proposed nutrient density score that includes food groups and nutrients to better align with dietary guidance

Adam Drewnowski, Johanna Dwyer, Janet C. King, and Connie M. Weaver

Current research on diets and health focuses on composite food patterns and their likely impact on health outcomes. The Dietary Guidelines for Americans (DGA) have likewise adopted a more food group–based approach. By contrast, most nutrient profiling (NP) models continue to assess nutrient density of individual foods, based on a small number of individual nutrients. Nutrients to encourage have included protein, fiber, and a wide range of vitamins and minerals. Nutrients to limit are typically saturated fats, total or added sugars, and sodium. Because current NP models may not fully capture the healthfulness of foods, there is a case for advancing a hybrid NP approach that takes both nutrients and desirable food groups and food ingredients into account. Creating a nutrient- and food-based NP model may provide a more integrated way of assessing a food's nutrient density. Hybrid nutrient density scores will provide for a better alignment between NP models and the DGA, a chief instrument of food and nutrition policy in the United States. Such synergy may lead ultimately to improved dietary guidance, sound nutrition policy, and better public health.

INTRODUCTION

The Dietary Guidelines for Americans (DGA) have been published every 5 years since 1980 by the US Department of Agriculture (USDA) and the US Department of Health and Social Services (DHHS). Intended to provide advice on how to select healthier diets,[1] DGA directives cover both dietary adequacy and moderation and are formulated in terms of individual nutrients, food categories, and food groups.[2–8] The DGA are the basis of much of the nutrition policy and nutrition education activities in the United States.

Food-based dietary advice was always an integral component of the DGA. The recommendation to "eat a variety of foods" was featured in the DGA as early as 1980.[2] The 1990 DGA were the first to include the USDA Food Guide as an indicator of a healthy dietary pattern.[4] The 2005 DGA recommended selecting nutrient-dense foods as opposed to foods providing discretionary calories to build healthy diets.[7] Discretionary calories were calculated based on the remaining energy available in the dietary patterns after nutrient needs were met.[9] Subsequent editions of the DGA have continued to emphasize the importance of specific food groups and of composite food patterns.[1,8] The emphasis

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Key words: Dietary Guidelines for Americans, dietary ingredients, food groups, nutrient density, nutrient profiling, nutrient-rich food index.

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was on creating nutrient-rich food patterns that met the recommendations for essential nutrients (protein, fiber, vitamins, and minerals) while limiting saturated fats, added sugars, and sodium.[1]

Despite decades of dietary guidance, most Americans' diets do not conform to recommendations.[10,11] The incidence of noncommunicable diseases (NCDs) is on the rise, and diet is an important modifiable risk factor in the development of NCDs, among numerous other social and biological contributors.[12] Applying the concept of nutrient density to the DGA might improve consumer food choices and aid in the construction of healthier diets.

Although the concept of nutrient-dense foods was included in the 2005 DGA, a formal definition of nutrient density was not provided.[1,7,8] A large literature on nutrient density of foods has grown since then.[13–25] Nutrient density of foods is commonly defined as the amount of selected nutrients per reference amount of food, the latter expressed as 100 kcal, 100 g, or a serving size.[26] The methods used to quantitatively assess nutrient quality of foods have collectively become known as nutrient profiling (NP). Nutrient profiling is an umbrella term that encompasses a variety of methods to either assign scores or classify foods into categories for a variety of applications (see Box 1[27]). The many NP models currently in existence are meant to distinguish between foods that are rich in essential nutrients (protein, fiber, vitamins, and minerals) and those that contain excessive amounts of saturated fats, added sugars, and sodium.[14,26,28] Nutrient profiling models have provided the quantitative scientific basis for front-of-pack (FOP) labeling, regulation of marketing and advertising to children, and product reformulations by the food industry.[14] Many other nutrition-related policies, such as taxation schemes, have also been based on nutrient-based NP models. However, nutrient density models have not been adopted by the DGA.

Arguably, there are parallels to be drawn between the DGA and the NP models because both are used for regulatory, policy, and educational purposes and for product portfolio and menu (re)formulations. Whereas the DGA apply to food patterns and total diets, NP models are applied to individual foods for the most part, and to a lesser extent to meals and menus.[29,30] Whereas the DGA are increasingly concerned with food categories, NP models continue to focus on the nutrient-to-energy ratio (caloric density) of individual foods.[13–25] Although some NP models do award extra points for the food content of vegetables, fruits, and (sometimes) nuts, their total scores tend to be driven by energy density and the food content of calories, sugars, and fat.[19] All too often, nutrient-rich foods are characterized by the absence of saturated fats, added sugars, and salt.[18,20–22] For example, the Chilean front-of-pack labeling NP model relies solely on the content of saturated fats, sugars, and salt. And, within the 2015–2020 edition of the DGA, foods in their "nutrient rich forms," defined as nutrient dense, were those with limited sodium, no added sugars, and no saturated fats.[1] These two examples are inconsistent with broad dietary guidance/dietary patterns recommended within the DGA that also consider nutrients and food groups to encourage.

As the DGA progressively embrace composite food patterns, it may be time for NP models to complement nutrients with food ingredients or desirable food groups because the selection of nutrient-dense foods forms the basic building blocks of healthy dietary patterns. This narrative review makes the case for a clearer definition of nutrient density that includes food groups by building on the importance of food-based dietary patterns within the DGA. A new hybrid approach to NP

Box 1 **Glossary of terms**

Nutrient Density: Nutrient content of foods, expressed per reference amount, typically 100 kcal, 100 g, or per serving. Most calculations have relied on nutrient-to-calorie ratios.

Nutrient Profiling (or Nutritional Profiling): The science of classifying or ranking foods based on their nutrient content per reference amount. Nutrient profiles can be based on qualifying nutrients (protein, fiber, and a variety of vitamins and minerals); on disqualifying nutrients (typically fat, sugars, and sodium), or some combination of both. Nutrient profiles are, for the most part, nutrient based, although some models consider food groups. Nutrient profiling has provided the scientific basis for education, regulation, and product reformulation by the food industry.[27]

Dietary Patterns: The combination of foods and beverages that constitute an individual's habitual consumption patterns over time. This approach takes into account customary ways of eating as well as the contributions of society and culture to dietary choices. Specific Dietary Guidelines for Americans examples include USDA Food Patterns and the Dietary Approaches to Stop Hypertension (DASH) Eating Plan.[1]

Food Groups: A method for grouping similar foods for descriptive and guidance purposes. Foods are typically grouped based on similarity in nutrient composition. The USDA Food Patterns aggregate foods into vegetables, fruits, grains, dairy, and protein foods. Food subgroups or categories can also be called out (eg, dark green vegetables, whole fruit, seafood, or whole grains). The Dietary Guidelines for Americans have used a food aggregation scheme based on approximately 100 foods.[1]

Nutrient Rich Food Index (NRF): A family of nutrient profiling models that balance nutrients to encourage against 3 nutrients to limit (saturated fats, sugars, and sodium), using 100 kcal as the basis of calculation. Various iterations of the score exist that vary in the number of positive nutrients included, ranging from 6 (NRF 6.3) to 15 (NRF 15.3). The NRF score can be applied to individual foods and to total diets.

modeling that takes both nutrients and desirable food groups into account is proposed.

The goal of this review is to demonstrate ways in which NP models that are both food and nutrient based can inform US food and nutrition policy, as exemplified by the DGA and health claims, intended to help consumers choose foods that can build healthy dietary patterns. This approach will take NP models beyond simplistic considerations of nutrients only to avoid unintended consequences that can arise due to a reductionist approach. Nutrient profiling modeling, in particular, could use a broader approach, where the nutrient density is considered not just for individual foods but also for meals, menus, and the total diet to reflect the various ways that individuals make food choices throughout the day and aid them in building healthy dietary patterns. Conversely, future DGA might benefit from more formal metrics of nutrient density, allowing a quantitative comparison among alternative healthy food patterns. The role of the DGA as a cornerstone of US nutrition policy and regulation further emphasizes the need to have a clear definition of nutrient density that is more congruent with the DGA dietary patterns.

THE DIETARY GUIDELINES FOR AMERICANS

Food-based recommendations

Table 1[1–8] summarizes the major DGA recommendations from 1980 to 2015. Many themes have remained consistent throughout. The trend from nutrients toward more food-based recommendations was more pronounced in the 2005, 2010, and 2015–2020 DGA.[1,7,8] For example, the 1980 and 1985 guidelines made the recommendation to "avoid too much sodium," whereas the 2005 advice shifted to "choose and prepare foods with little salt."[2,3,7] Likewise, the 2005 DGA added specific recommendations on the dairy food groups and choosing more whole grains and provided more details on the subtypes of vegetables to consume, all of which continued in later editions.[1,7,8] The DGA became more food-specific by highlighting the importance of including leafy green vegetables, whole fruits, nuts, and whole grains and incorporating seafood and plant protein foods into one's diet (see Table 1[1–8]). These food group–based suggestions have become the basis of the healthy dietary patterns recommended in recent editions of the DGA.[1,8]

Healthy dietary patterns

More recent DGA have shifted the focus to not only achieving dietary adequacy but also emphasizing the associations between food patterns and reduced NCD risk. The three eating patterns provided within the 2015–2020 DGA—Healthy US-Style (Appendix 3 of the 2015–2020 DGA[1]), Healthy Vegetarian (Appendix 4 of the 2015–2020 DGA[1]), and Healthy Mediterranean-Style (Appendix 5 of the 2015–2020 DGA[1])—illustrate how the guidelines could be met in a variety of ways.[1] Each pattern uses nutrient-dense foods to optimize nutrient intake while limiting "empty" calories from added sugars, alcohol, and saturated fats.[31] The dietary patterns within the DGA are food-based dietary patterns designed to help individuals choose foods that will enable them to meet their daily nutrient requirements without exceeding limits, such as those for saturated fats, added sugars, sodium, and total calories. In addition to meeting essential nutrient needs, research also shows that adherence to a recommended food-based dietary pattern may be inversely associated with chronic disease risk.[1]

The 2015–2020 DGA stressed that "the components of the eating pattern [including nutrients and food groups] can have interactive and potentially cumulative effects on health."[1] Those statements by the DGA were consistent with nutritional epidemiology studies suggesting that dietary patterns that improve the intake of several key nutrients were more closely associated with reducing risk of diet-related chronic diseases than were single nutrients.[32,33] For example, dietary patterns that include milk, yogurt, and cheese provide calcium and vitamin D, both of which are required for efficient calcium absorption and mineral deposition in bones to reduce the risk of osteoporosis.[34] Similarly, the dietary sodium-to-potassium ratio has been shown to be a better predictor of cardiovascular disease and all-cause mortality than the intakes of either nutrient alone.[35] Therefore, the beneficial health effects of foods and food groups as found in epidemiological and intervention research often cannot be directly extrapolated to nutrients.[1,36,37] These examples suggest that nutrient density profiles that include food groups are essential parts of dietary patterns.

Consumer adherence to the DGA-inspired dietary patterns has been operationalized using the Healthy Eating Index (HEI), a measure of dietary compliance with the DGA.[38] The 2005 and later versions of the HEI differed from earlier iterations in they were nutrient density based (ie, focused on the food groups and nutrients per 1000 kcal), providing a link between nutrient density and NP.[38–40] The earliest 1995 version of the HEI had 5 major food factors: total fat, saturated fats, total cholesterol, sodium, and dietary variety.[41] The HEI has been revised several times to conform with the successive DGA, released every 5 years[39,40] (see Table 2[38] for a comparison of HEI scoring systems). The latest HEI includes 7 food groups (fruits,

Table 1 **Major recommendations in US Dietary Guidelines from 1980 to 2015**

	1980, USDA and DHHS (1980)[2]	1985, USDA and DHHS (1985)[3]	1990, USDA and DHHS (1990)[4]	1995, USDA and DHHS (1995)[5]	2000, USDA and DHHS (2000)[6]	2005, USDA and DHHS (2005)[7]	2010, USDA and DHHS (2010)[8]	2015–2020, USDA and DHHS (2016)[1]
Variety	Eat a variety of foods	Eat a variety of foods	Eat a variety of foods	Eat a variety of foods	Let the pyramid guide your food choices	Consume a variety of nutrient-dense foods	Include vegetables, fruits, whole grains, and dairy	Focus on variety, nutrient density, and amount
Dietary Patterns						Meet nutrient intakes within energy needs	Meet nutrient needs over time at an appropriate calorie level	Follow a healthy eating pattern across the lifespan
Food groups								
Grains, Vegetables, Fruits	Eat foods with adequate starch and fiber	Eat foods with adequate starch and fiber	Choose a diet with plenty of vegetables, fruits, and grain products	Choose a diet with plenty of grain products, vegetables, and fruits	Choose a variety of grains daily, especially whole grains	Choose fiber-rich fruits, vegetables, and whole grains often. At least half from whole grains	Increase vegetables and fruit. Consume at least half of all grains as whole grains. Limit refined grains	A healthy eating pattern: grains, (50% whole grains), fruits, esp. whole, and variety of vegetables
Dairy						Consume 3 cups/d of fat-free or low-fat milk or milk products	Increase intake of fat-free or low-fat milk and milk products	A healthy eating pattern: fat-free or low-fat dairy
Protein foods						Make choices that are lean, low-fat, or fat-free	Choose a variety of protein foods. Increase seafood amount and variety	A healthy eating pattern includes a variety of protein foods
Nutrients and food components to limit								
Fats	Avoid too much fat, saturated fat, and cholesterol	Avoid too much fat, saturated fat, and cholesterol	Choose a diet low in fat, saturated fat, and cholesterol	Choose a diet low in fat, saturated fat, and cholesterol	Choose a diet that is low in saturated fat, cholesterol, moderate in total fat	Consume <10% of calories from saturated fatty acids and <300 mg/day of cholesterol	Consume <10% of calories from saturated fats and <300 mg/day of cholesterol	Consume <10% of calories from saturated fats
Sugars	Avoid too much sugar	Avoid too much sugar	Use sugars only in moderation	Choose a diet moderate in sugars	Choose beverages and foods to moderate your intake of sugars	Choose foods with little added sugars. Eat sugars and starches less often	Reduce the intake of calories from added sugars	Consume <10% of calories from added sugars

(continued)

Table 1 **Continued**

	1980, USDA and DHHS (1980)[2]	1985, USDA and DHHS (1985)[3]	1990, USDA and DHHS (1990)[4]	1995, USDA and DHHS (1995)[5]	2000, USDA and DHHS (2000)[6]	2005, USDA and DHHS (2005)[7]	2010, USDA and DHHS (2010)[8]	2015–2020, USDA and DHHS (2016)[1]
Sodium	Avoid too much sodium	Avoid too much sodium	Use salt and sodium only in moderation	Choose a diet moderate in salt and sodium	Choose sensibly: choose and prepare foods with less salt	Consume <2300 mg of sodium per day. Choose foods with little salt and rich in potassium	Reduce sodium to <2300 mg/day (1500 mg/day for some groups)	Consume <2300 mg per day of sodium
Alcohol	If you drink alcohol, do so in moderation	If you drink alcoholi, do so in moderation	If you drink alcohol, do so in moderation	If you drink alcohol, do so in moderation	If you drink alcohol, do so in moderation	If you drink alcohol, do so sensibly and in moderation	If alcohol is consumed, it should be consumed in moderation	If alcohol is consumed, it should be consumed in moderation

Abbreviations: DHHS, US Department of Health and Human Services; USDA: US Department of Agriculture.

vegetables, grains, dairy, protein foods, fats, and refined grains), as well as sodium, saturated fats, and sugars (see Table 2[38]). Several studies have validated the HEI as a sensitive tool to assess overall diet quality and have shown associations between the HEI and health outcomes.[39,40,42]

Whereas the HEI includes both nutrients and food groups, other measures of diet quality have been based on food groups alone.[42] Dietary Approaches to Stop Hypertension (DASH)–compliant and Mediterranean diet scores are two prominent examples.[42,43] Although a discussion of the methods to assess total diet quality and their associations with health outcomes is outside the scope of this narrative review, the complex issues involved have been summarized well by others.[43,44] However, it is important to note that measures of overall diet quality almost always incorporate food groups, as seen with the HEI. That approach could be extended to NP models that measure the nutrient density of individual foods, which can be used to build these healthy dietary patterns.

NUTRIENT DENSITY IN FEDERAL REGULATIONS AND GUIDELINES

The Dietary Guidelines for Americans 2005–2020

The 2005 DGA were the first to directly promote the consumption of nutrient-dense foods.[45] However, the nutrient density concept remained undefined both in the 2005 and the 2010 DGA, and no quantitative algorithm was provided. Instead the DGA subjectively listed a number of food groups considered to be nutrient dense or nutrient rich that appeared to be based more on nutrients to limit, rather than nutrients to encourage. The list included whole grains, fruits, vegetables, fat-free or low-fat milk and milk products, seafood, lean meats and poultry, eggs, beans and peas, and nuts and seeds, all prepared without added fats or sugars. Many of those foods did, in fact, have high nutrient density scores that had been calculated using the Nutrient Rich Foods (NRF)[13,16] index and some other NP models.[46]

Nutrient density in the 2015–2020 DGA was loosely defined as those foods that provided substantial amounts of nutrients and relatively little dietary energy.[1] Individuals were urged to select foods from certain food groups with an emphasis on foods in their nutrient-rich forms. A list similar to that in the 2010 DGA was provided. The rationale for recommending these specific foods was that such foods contain nutrients and other beneficial constituents without dilution by "empty calories," that is, without the addition of energy from solid fats and added sugars.

Table 2. **Comparison of the components and scoring standards in the Healthy Eating Index (HEI): HEI-2015, HEI-2010, and HEI-2005**

				Standard for maximum points[a]			Standard for minimum score of zero[a]		
	Construct	Maximum points	Component	2005	2010	2015	2005	2010	2015
Adequacy	Fruits	10	Total fruits (5 points)	≥0.8 cup	≥0.8 cup	≥0.8 cup	No fruit	No fruit	No fruit
			Whole fruits (5 points)	≥0.4 cup	≥0.4 cup	≥0.4 cup	No whole fruits	No whole fruits	No whole fruits
	Vegetables	10	Total vegetables (5 points)	≥ 1.1 cup	≥ 1.1 cup	≥ 1.1 cup	No vegetables	No vegetables	No vegetables
			Dark green/orange vegetables and legumes (5 points)	≥ 0.4 cup	–	–	No dark green/orange vegetables and legumes	–	–
			Greens and Beans (5 points)	–	≥ 0.2 cup	≥ 0.2 cup	–	No dark green vegetables or legumes[b]	No dark green vegetables or legumes[b]
	Grains	10	Total grains (5 points)	≥ 3.0 oz.	–	–	No grains	–	–
			Whole grains[c] (5 points/10 points)	–	≥ 1.5 oz.	≥ 1.5 oz.	No whole grains	No whole grains	No whole grains
	Dairy	10	Milk/dairy[d] (10 points)	≥1.3 cups	≥1.3 cups	≥1.3 cups	No dairy	No dairy	No dairy
	Protein foods	10	Meat and beans	≥ 2.5 oz.	–	–	No meat or beans	–	–
			Total protein foods (5 points)	–	≥ 2.5 oz.	≥ 2.5 oz.	–	No protein foods	No protein foods
			Seafood and plant proteins (5 points)	–	≥ 0.8 oz.	≥ 0.8 oz.	–	No seafood or plant proteins	No seafood or plant proteins
	Fats	10	Oils	≥ 12 g of oil	–	–	No oil	–	–
			Fatty acid ratio	–	(PUFAs + MUFAs)/SFAs ≥ 2.5	(PUFAs + MUFAs)/SFAs ≥ 2.5	–	(PUFAs + MUFAs)/SFAs ≤ 1.2	(PUFAs + MUFAs)/SFAs ≤ 1.2
Moderation	Refined grains	10	Refined grains	–	≤ 1.8 oz.	≤ 1.8 oz.	–	≥ 4.3 oz.	≥ 4.3 oz.
	Sodium	10	Sodium	≤ 0.7 g	≤ 1.1 g	≤ 1.1 g	≥ 2.0 g	≥ 2.0 g	≥ 2.0 g
	Empty calories	20	SoFAAs (2005) empty calories (2010) (20 points)	≤ 20% of energy	≤ 19% of energy	–	≥ 50% of energy	–	–
			Added sugar (10 points)	–	–	≤ 6.5% of energy	–	–	≥ 26% of energy
			Saturated fat (10 points)	≤ 7% of energy	–	≤ 8% of energy	≥ 15% of energy	–	≥ 16% of energy

[a]All standards represent amounts per 1000 kcal
[b]Legumes includes beans and peas
[c]Whole grains received a maximum of 5 points in HEI-2005 and a maximum of 10 points in HEI-2010 and HEI-2015
[d]Component name was Milk in HEI-2005 and Dairy in HEI-2010 and HEI-2015
Adapted from the National Cancer Institute[38]

Although the 2015–2020 DGA featured the concept of nutrient density even more prominently than before, no quantitative definition was provided. The levels of selected nutrients that are considered substantial are also left vague. By contrast, NP models are very precise about amounts of nutrients per calorie, nutrients per gram, or nutrients per standard serving. Many NP models have transparent algorithms that are open for inspection and review.[15–17,19] A better alignment between the DGA concepts and the NP literature would be beneficial for both.

Defining nutrient density solely by the absence of sugars, sodium, or saturated fats has drawbacks. A continued focus on nutrient-based dietary guidance may be taken to mean that foods that are sugar- or fat-free are particularly healthful, whereas all others are not.[47] One unintended consequence might be reduction in the consumption of otherwise nutrient-rich foods because of a single component of concern. For the DGA to be effective, attention must be paid to defining specific, nutrient-dense food choices within each food group.

An operational definition of nutrient density in the DGA would provide more transparency and perhaps eliminate some discrepancies between perceptions and reality. For example, foods that are high in critical shortfall nutrients are often not considered nutrient rich because they also contain nutrients to limit. Cashews, not mentioned in the DGA, likely because of their saturated fat content, also contain protein, calcium, and other micronutrients.[1] Chocolate milk, yogurt, ready-to-eat cereals, avocados, almonds, and eggs contribute many of the shortfall vitamins and minerals, but they also contain added sugars, salt, or saturated fats.[47] The best example, cheese, can be an excellent source of calcium and protein but, by its very nature, also contains sodium and saturated fats. Partly because of a lack of consensus and nutrient limitations of current NP profiles, not all healthy foods are designated as nutrient rich. Nutrient profiling methods show that some foods viewed as "unhealthy" can have a very favorable ratio of nutrients to calories, easily qualifying them as nutrient rich. Conversely, using NP methods, it can be shown that some foods designated as nutrient rich have high scores because of their low energy density, not a high content of index nutrients.

The US-regulated nutrient content claim "healthy"

Recent activities related to the updating of the nutrient content claim for "healthy," regulated by the US Food and Drug Administration (FDA), provide a further illustration of the shift from nutrients to foods, food groups, and dietary ingredients. According to the FDA's current definition, "healthy" is a nutrient content claim that can be used if the food meets certain nutrient conditions and, when used with an explicit or implicit claim or statement about a nutrient (eg, "healthy, contains 3 grams of fat"), suggests that a food, because of its nutrient content, may be useful in creating a diet that is consistent with dietary recommendations.[48,49] For a food to bear a "healthy" nutrient content claim, it must meet specific criteria for nutrients to limit in the diet as specified in the DGA, such as total fat, saturated fats, cholesterol, sodium, as well as requirements for nutrients to encourage in the diet, including vitamin A, vitamin C, calcium, iron, protein, and fiber. The criteria are linked to elements in the Nutrition Facts Panel and serving size regulations. The nutrient criteria to use the claim can vary for different food categories (eg, fruits and vegetables or seafood and game meat). In 2015, the food company KIND LLC submitted a citizen petition requesting that the FDA revisit the definition of what constitutes a "healthy" food.[50] The KIND bars, which contained nuts, did not meet the nutrient content claim for "healthy" because they contained more than 1 g of saturated fats per Reference Amount Customarily Consumed and because >15% of energy came from saturated fats. The KIND petition argued that nutrient density was more important than low fat content. One argument was that for foods to be labeled as "healthy," they needed to meet low-fat and low-saturated fat claims, regardless of their nutrient density. That meant that low-fat foods could be marketed as healthy whereas nuts, avocados, and salmon could not.[50] The KIND petition noted that current science no longer supports standards that are purely nutrient based.[50]

During a public consultation period, the FDA heard from multiple stakeholders that the current definition of healthy, based solely on the nutrient content of food, should be updated to include food groups.[51,52] Although the FDA has long favored the nutrient-based approach, there are signs that certain food groups or ingredients may be recognized as intrinsically healthy by the agency. In that case, there is a need to adapt current NP methods to facilitate federal regulations, recommendations, and guidelines.

The principles behind the development of a nutrient density score for individual foods that includes food groups (or a hybrid nutrient density score) and the potential applications of the NP methodology to 2020 dietary guidance are outlined below.

ENERGY DENSITY AND NUTRIENT DENSITY METRICS

Energy density of foods and beverages

Energy density represents the energy content of a standard weight or volume of food or beverage (kcal/100 g).

Because energy density is inversely linked to the water content of foods, foods with a high energy density tend to be dry while foods with a low energy density are high in water. The continuum of energy density in foods runs from water (0 kcal/100 g) to pure carbohydrate or protein (400 kcal/100 g) to oil (900 kcal/100 g). Granulated sugar, for example, contains no moisture and is pure carbohydrate, so its energy density is 400 kcal/100 g; in contrast, the energy density of a sugar-sweetened beverage is around 40 kcal/100 g because it contains both sugar and water.

The energy density of low-moisture, high-fat foods such as dark chocolate (600 kcal/100 g) and potato chips (520 kcal/100 g) is several times that of high-moisture foods such as carrots (40 kcal/100 g) and spinach (10 kcal/100 g). Although the energy density of diets may play a small role in regulating total calorie intake and maintaining a healthy body weight,[53–55] it is an insufficient tool for choosing and building healthy dietary patterns because it does not consider the nutrient content of the food.

Nutrient profiling models to assess nutrient density of foods and beverages

Nutrient density is usually described as the concentration of nutrients per 100 kcal of food, but sometimes it is stated per 100 g or serving size instead.[26] When expressed per 100 kcal, it represents the ratio of nutrients to energy. Numerous approaches are in use to determine the nutrient density of a food. Current NP methods, mostly nutrient based, do not handle such issues as bioavailability, nutrient interactions, or nutrient balance.

Some key considerations in developing nutrient density models have been identified in prior research.[47] First, nutrients to encourage and nutrients to limit are selected based on nutrients of public health concern, as identified through analyses of population dietary patterns. Whether fortified foods are included or not is a judgment that needs to be made. In general, nutrient bioavailability has not been considered, although it should be. Iron and calcium from animal sources are more bioavailable than iron and calcium from some plant sources, and protein quality can also vary.[56,57] Bioactive compounds, including polyphenols, flavonoids, and other antioxidants, are not typically included in NP models, largely because they lack detailed nutrient data, not to mention Dietary Reference Intake values.[58,59] Nutrient profiling models can be compensatory or not. Compensatory models balance beneficial nutrients against nutrients to limit; noncompensatory models focus on nutrients to limit alone. The calculations can be based on 100 g, 100 kcal, or serving size. Nutrient profiling models need to be validated to independent measures of a healthy diet.[14]

The NRF index 9.3, initially developed in 2006, was based on the content of protein, fiber, vitamin A, vitamin C, vitamin E, calcium, iron, potassium, magnesium, saturated fats, sugars, and sodium, all expressed per 100 kcal of food.[16] Other variants of the NRF family of scores exist, with the number of nutrients to encourage in the calculation ranging from 5 to 23.[16,60] This transparent method for calculating a nutrient density score, well documented in the literature, is based on public health principles and is flexible enough to allow for updating as nutrition science evolves.

A number of other NP models for foods have been described in the literature, in addition to the NRF.[15–17,19,20,23–25] Only a few are hybrid scores combining nutrients and food groups. The UK Food Standards Agency–Ofcom and the Australian Health Star Rating scores award extra points for a food's content of fruit, vegetables, and nuts.[17,19] The French NutriScore features vegetables, fruit, and nuts, whereas SENS (Système d'Etiquetage Nutritionnel Simplifié [Simplified Nutrition Labeling System]) lists fruit, vegetables, legumes, and nuts.[18] Most of these NP models were developed for a specific purpose, such as FOP labeling or marketing to children, and tend to focus on energy density and nutrients to limit. By focusing exclusively on energy and macronutrients, many such NP models fail to capture the true nutrient density of a food, instead capturing little more than energy density.

In particular, for NP models that calculate nutrient density per 100 g of food, these scores more closely approximate energy density rather than nutrient density per 100 kcal.[61] The NRF index avoids these problems and provides a more balanced picture of the overall nutrient density of a food, as compared with the other NP models currently available.

THE CASE FOR A HYBRID NUTRIENT DENSITY SCORE

A proposed hybrid nutrient density score is described in Box 2 and builds upon the NRF 6.3 to incorporate the food groups recommended in the 2015–2020 DGA's Healthy US-Style Eating Pattern.[1] Food groups were selected based on those to encourage in the 2015–2020 DGA. Specifically, the 2015–2020 DGA states that a healthy dietary pattern includes a variety of vegetables from all of the subgroups; fruits; grains, at least half of which are whole grains; fat-free or low-fat dairy; a variety of protein foods; and oils.[1] Some foods in the protein food group were omitted because protein is included as a nutrient to encourage in the equation. Nuts and seeds were included as a particular type of protein food to encourage due to their other potential

Box 2 Calculation of the proposed hybrid nutrient density score

Hybrid Nutrient Density Score = (NR+FR−LIM) × 100
Where:

NR (qualifying nutrients to encourage) =

$$\sum_{i=1}^{6} \frac{Nutrient\ per\ 100\ kcal_i}{DV_i}$$

FR (qualifying food groups to encourage) =

$$\sum_{i=1}^{5} \frac{Food\ Group\ per\ 100\ kcal_i}{DGA\ Recommendation_i}$$

LIM (disqualifying nutrients to limit) =

$$\sum_{i=1}^{3} \frac{Nutrient\ per\ 100\ kcal_i}{DV_i}$$

Daily Values for Nutrients to Encourage[a, 65,66]**:** protein, 50 g; fiber, 28 g; vitamin D, 20 μg; potassium, 4700 mg; calcium, 1300 mg; and iron, 18 mg.

Food Groups to Encourage[b, 1]**:** whole grain, 3 oz equivalents; vegetables, 2.5 cup equivalents; fruit, 2 cup equivalents; dairy, 3 cup equivalents; and nuts and seeds, 0.7 oz equivalents.

Daily Values for Nutrients to Limit[65,66]**:** sodium, 2300 mg; total sugars,[c] 125 g; saturated fats, 20 g.

[a]Note: The contribution of nutrients to encourage toward the DV is capped at 100%.
[b]Based on a 2000 calorie US-Style Healthy Eating Pattern. See Appendix 3 of the 2015–2020 Dietary Guidelines for Americans.[1]
[c]There is no daily value for total sugars, 125 g was used based on the following reference.[16]

health benefits.[62–64] The saturated fat content of the dairy food group is considered through the inclusion of saturated fats as a nutrient to limit in the equation. Lastly, oils are not included in the proposed model. The 2015–2020 DGA caution that oils are a concentrated source of calories and that the amount consumed should be within the Acceptable Macronutrient Distribution Range (AMDR) for total fats without exceeding calorie limits.[1] Therefore, oils are treated as neutral in the hybrid nutrient density score, and only saturated fats are penalized. These food groups are also included in the 2010 and 2015 HEI. Additional research to optimize the components included in the hybrid nutrient density score and to validate it against other known indicators of nutrient density or diet quality, as well as dietary and health outcomes, is necessary to provide a more in-depth justification for these decisions.

Incorporating food groups into a nutrient density model means that this tool can be used to help individuals build a healthy overall diet and to inform taxation, FOP labels, and other policies to influence dietary choices. Policy-based initiatives, such as taxation and FOP labels, need quantitative methods to determine which foods will be impacted by the policy (ie, be taxed or bear a FOP label). A hybrid nutrient density score, rather than a NP that only considers nutrients to limit, may better help consumers make healthy food choices. For example, current proposals for FOP labeling in Canada, based only on saturated fat, sodium, and added sugar, would require that several nutrient-dense foods, including foods such as low-fat chocolate milk and whole grain–fortified ready-to-eat cereal, would bear warning labels despite providing underconsumed nutrients or food groups.[67] An additional consideration is that those nutrients that contribute to a healthy diet and that have been identified as being of public health concern but are not currently covered by the existing NP models are taken into account. For example, earlier versions of the NRF did not include vitamin D because nutrient composition data were not available. However, vitamin D has now been identified as a nutrient of public health concern by the 2015–2020 DGA and will be mandatorily declared on US nutrition facts panels starting in January 2020.[1,16,68] Iodine content of foods is a component of nutrient composition databases in France but not in the United States. Calcium is not the only valuable nutrient in milk and milk products. This hybrid nutrient density approach, which includes both nutrients and food groups, may help to bridge the gap between the current DGA and the nutrient density literature.

Box 2 [1,16,69,70] compares the proposed framework for a hybrid nutrient density score to the already established NRF 6.3 score. Similar to the NRF model, the prototype hybrid nutrient density score was calculated by adding the relative contribution to the daily value (DV) of each of 6 nutrients, capped at 100%, to the sum of food groups to encourage, calculated as the percentage contribution to daily recommended intakes at the 2000 calorie level, minus the sum of the percentage contribution of nutrients and components to limit as compared with the DV (see Box 2 [1,16,69,70] for the proposed equation).

As can be seen in Table 3, the incorporation of food groups to encourage into the NRF to create the hybrid nutrient density score generates a higher score for fruits, vegetables, dairy, whole grains, and nuts and seeds than the NRF without these foods. This could have an impact on recommendations. For example, brown rice and white rice have similar NRF 6.3 scores, 5 and 3, respectively. However, using the hybrid nutrient density score, brown rice scores 38 because of its contribution to the daily whole grain recommendation, whereas white rice remains at 3. Comparing whole wheat bread to white bread, whole wheat bread scores 20 and white bread scores 12 using NRF 6.3; the hybrid nutrient density score generates scores of 72 for whole

Table 3 **Comparison of the proposed hybrid nutrient density score and the Nutrient Rich Food Index 6.3 (NRF 6.3)**

Food	NRF 6.3 Score[a,b]	Proposed Hybrid Nutrient Density Score[c,d]
White rice	3	3 (no change in score; no food groups)
Brown rice	5	38 (contribution of WG food group)
White bread	12	15 (minimal contribution of WG food group)
Whole-wheat bread	20	72 (contribution of WG food group)
Whole-grain toasted oat unsweetened breakfast cereal	73	102 (contribution of WG food group)
Raw apple	8	95 (contribution of fruit food group)
Canned peaches in juice	5	51 (contribution of fruit food group)
Raw broccoli	77	224 (contribution of vegetable food group)
Canned green peas	27	64 (contribution of vegetable food group)
Calcium-fortified skim milk	73	112 (contribution of dairy food group)
2% milk	25	52 (contribution of dairy food group)
1% chocolate milk	22	45 (contribution of dairy food group)
Whole milk plain yogurt	7	29 (contribution of dairy food group)
Low-fat, fruit-flavored yogurt	7	21 (contribution of dairy food group)
Reduced-sodium canned vegetable soup	20	46 (contribution of vegetable food group)
Roasted mixed nuts	7	195 (contribution of nuts and seeds food group)

Abbreviation: WG, whole grain.

[a]NRF 6.3 scores were calculated for the example foods using Food and Nutrient Database for Dietary Studies (FNDDS) 2013–2014 data according to the following equation: NRF 6.3 = [(protein g/50 g $\times$ 100) + fiber g/28 g $\times$ 100)+ (vitamin D μg/20 μg $\times$ 100) + (potassium mg/4700 mg $\times$ 100) + (calcium mg/1300 mg $\times$ 100) + (iron mg/18 mg $\times$ 100)] – [(sodium mg/2300 mg $\times$ 100) + (total sugars/125 g $\times$ 100) + (saturated fats g/20 g $\times$ 100)].

[b]The nutrients to encourage in the NRF 6.3 score were updated to include those on the recently finalized Nutrition Label Reform nutrition facts panel and those identified in the 2015–2020 Dietary Guidelines for Americans nutrients of public health concern.

[c]Food groups included in this preliminary version of the hybrid nutrient density score were whole grain, fruit, vegetable, dairy, and nuts and seeds. Further testing and validation of a hybrid nutrient density score would be needed to finalize the optimal list of recommended food groups to include.

[d]Hybrid Nutrient Density scores were calculated for the example foods using FNDDS 2013–2014 data according to the following equation: Hybrid Nutrient Density Score = [(protein g/50 g $\times$ 100) + (fiber g/28 g $\times$ 100)+(vitamin D μg/20 μg $\times$ 100) + (potassium mg/4700 mg $\times$ 100) + (calcium mg/1300 mg $\times$ 100) + (iron mg/18 mg $\times$ 100)] + [(whole grain oz equivalent/3 oz equivalent $\times$ 100) + (vegetables cup equivalent/2.5 cup equivalent $\times$ 100) + (fruit cup equivalent/2 cup equivalent $\times$ 100) + (dairy cup /3 cup equivalent $\times$ 100) + (nuts and seeds oz equivalent/0.7 oz equivalent $\times$ 100)] – [(sodium mg/2300 mg $\times$ 100) + (total sugar equivalents g/125 g $\times$ 100) + (saturated fats g/20 g $\times$ 100)].

wheat bread and 15 for white bread, producing a much larger difference between these 2 foods. In both examples, adding the whole grain food group to the hybrid nutrient density score helped to better differentiate the DGA-recommended whole grain products. Among dairy products, the hybrid nutrient density score is higher than the NRF 6.3 score for both skim milk and 2% milk, as well as low-fat and whole milk yogurt, because all contribute to recommended daily dairy servings. However, the presence of components to limit (eg, saturated fats and added sugars) in the higher fat and flavored products lowers their score: the hybrid nutrient density score of skim milk is 112, whereas that of 2% milk is 52 and 1% chocolate milk is 45; and the score for plain whole milk yogurt is 29, whereas that of flavored low-fat yogurt is 21. Other foods from DGA-recommended food groups that result in a higher hybrid nutrient density score compared with the NRF 6.3 score include fortified whole grain breakfast cereal (from 73 to 102), raw apples (from 8 to 95), raw broccoli (from 77 to 224), reduced-sodium vegetable soup (from 20 to 46), and roasted mixed nuts (from 8 to 195). Box 2 [1,16,69,70] provides further details on the proposed hybrid nutrient density score calculation and sources of the data used to construct it.

There are several key considerations in developing the hybrid score. They include selecting appropriate nutrients for inclusion, using appropriate units, considering nutrient bioavailability and fortification, categorizing foods based on nutrient density, determining the availability of data to calculate a nutrient density score, and testing the score's utility and applications.[47,71] How these considerations were used in the development of the NRF 6.3, upon which the hybrid nutrient density score is based, has been described elsewhere.[13,16,71] More rigorous scientific study and debate on these considerations and testing of the hybrid nutrient density score's utility will be needed if it is to be adopted. However, it is suggested that the selection of nutrients and food groups for inclusion in the hybrid nutrient density score should be guided by the current 2015–2020 DGA recommendations for both nutrients and food groups and calculated based on 100 kcal of food to avoid conflating energy density and nutrient density.[61] Any further categorization should be appropriate to the specific application being considered (eg, product reformulation, FOP labeling, or consumer education) because each application has its own unique considerations and constraints.[28]

The hybrid nutrient density score should also consider the contribution of the nutrients provided through fortification.[45,72] Fortification plays an important role in helping the population increase intake of underconsumed nutrients, and it may be particularly important for certain populations. For example, the elderly and young children require particularly nutrient-dense diets so they can meet their nutrient needs in the face of lower calorie requirements; this can be achieved through the judicious use of fortified foods.[65] In both the NRF family of scores and the proposed hybrid nutrient density score, the maximum score a food can achieve for each nutrient to encourage is 100% of the DV; therefore, fortification beyond this point adds no additional benefit to the score.

A hybrid nutrient density score can be calculated for processed foods.[66] Although some NP models, such as the Pan American Health Organization's and Chile's FOP scores, penalize all processed foods, developing criteria by which to succinctly assess the overall contribution of a food to the diet may be more helpful in guiding individuals to build healthy dietary patterns.[20,21] This is because nearly all foods require some processing before consuming and processed foods currently contribute in a meaningful way to many underconsumed nutrients.[66] To be useful, a score must assess the overall contribution of a food (including nutrients and food groups to encourage), rather than only looking at the nutrients to limit or the level of processing.

Hybrid NP models avoid the criticism of nutrition reductionism by including food groups and not focusing solely on nutrients.[32,33] The healthfulness of foods is not readily captured by a score based only on a few nutrients. A food-based model of nutrient density also lends itself more readily to evaluation of the cost of healthy diets. Whereas individual nutrients can be obtained at low or high cost, the cost of foods and food groups can be pinpointed more precisely.

CONCLUSION

The 2015–2020 DGA have emphasized the importance of healthy food choices and dietary patterns.[1] That trend is likely to continue in future DGA editions. The FDA has explored the expansion of the regulated term "healthy" to include desirable food groups and dietary ingredients. Nutrient profiling models provide a quantitative tool to guide these policies and evaluate their effectiveness in the marketplace for shifting food choices and dietary patterns. However, most existing NP methods are still nutrient based and many are focused on selected nutrients (fat, saturated fats, sugars, and salt) as opposed to the total nutrient density of the food or beverage.

Hybrid NP systems that feature nutrients, food groups, and dietary ingredients may provide for a better alignment between quantitative measures of nutrient density and their policy applications. Ultimately, the goal of NP models is to assist individuals, institutions, and governments to identify food patterns that are healthy, affordable, and nutrient rich. This requires a great deal of information about nutrient composition of foods, including data on phytochemicals, antioxidants, and other bioactives. Conclusions about the relative weighting of components in dietary patterns quality scores such as the HEI or nutrient density profiles and their links to chronic disease risk must rely on various types and multiple sources of evidence and not only observational studies. Being able to identify nutrient-rich food patterns that are affordable, appealing, and adequate, but not excessive in energy, will benefit public health.

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